VII. Causes Of Water Pollution

Pollution is an alteration of the physical, chemical, biological, bacteriological, or radiological properties of water that result in an impairment of designated uses. In assessing the causes of pollution in streams and lakes, the Division follows the guidance provided by EPA. In order to help standardize the naming of pollutants, EPA's Assessment Database (ADB) has a menu of potential pollutants that can be selected for impaired streams. Additionally, states can create subcategories. For example, "nutrients" is an EPA category in the ADB. Tennessee has added "nitrate+nitrite" and "total phosphorus" as sub-categories.

A. Causes of Pollution in Streams and Rivers

Pollutants such as siltation, suspended solids, nutrients, organic enrichment, and low dissolved oxygen are the leading causes of impairment in Tennessee streams. Silt and suspended solids impact streams by eliminating habitat, blocking light penetration, and smothering aquatic life. Organic enrichment caused by excessive nutrients or BOD stimulates algae growth which causes wide fluctuations in dissolved oxygen levels (Figure 11). These factors alter biological communities to favor species tolerant for these conditions. The public's uses of these streams are impacted when biological integrity goals are not met. Other common pollutants in streams include toxic substances, bacteria, flow alteration and habitat destruction.

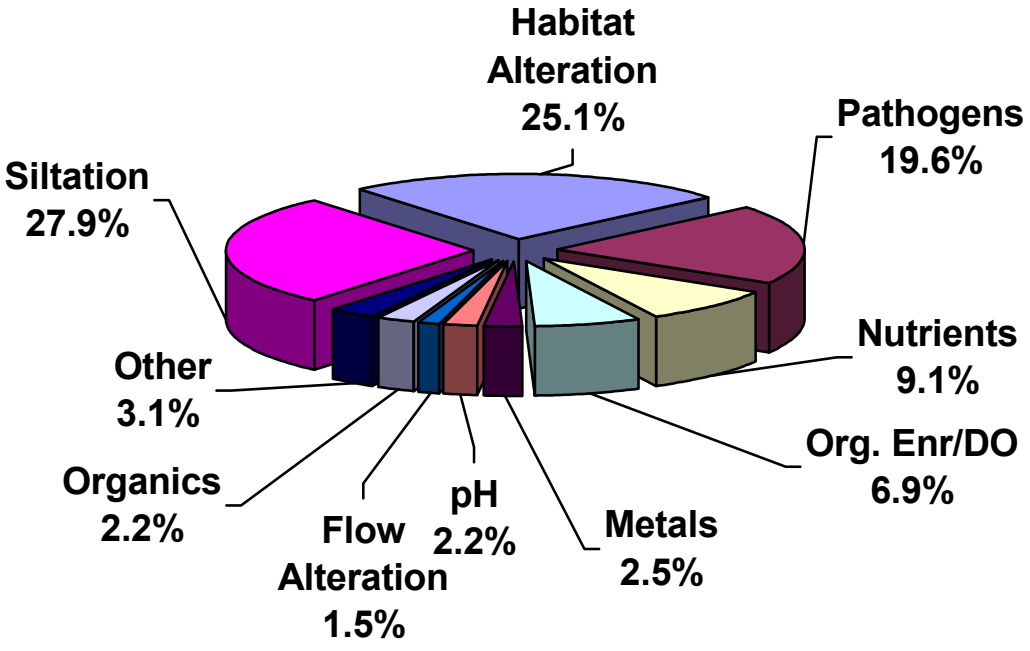

Figure 11: Relative Impacts of Pollution in Assessed Rivers and Streams

1. Siltation

The most frequently cited pollutant in Tennessee is siltation, impacting over 4,860 miles of streams. Siltation is generally associated with land disturbing activities such as agriculture and construction. Some of the significant economic impacts caused by siltation are increased water treatment costs, filling in of reservoirs, loss of navigation channels, and increased likelihood of flooding.

Silt alters the biological properties of waters by:

- Smothering eggs and nests of fish.
- Transporting other pollutants, in possibly toxic amounts, or providing a reservoir of substances that may become concentrated in the food chain.
- Clogging the gills of fish and other forms of aquatic life.
- Interfering with fish ability to see food.
- Covering substrate that provides habitat for aquatic insects, a main prey of fish.
- Reducing biological diversity by altering habitats to favor burrowing species.
- Accelerating growth of submerged aquatic plants and algae.

Silt alters the chemical properties of waters by:

- Interfering with photosynthesis.
- Decreasing available oxygen due to decomposition of organic matter. Decomposing organic matter in the absence of light causes a deficiency in dissolved oxygen.
- Increasing nutrient levels that accelerate eutrophication in reservoirs.
- Transporting organic chemicals and metals into the water column (especially if the original disturbed site was contaminated).

Silt alters the physical properties of waters by:

- Reducing or preventing light penetration.
- Changing temperature patterns.
- Decreasing the depth of pools or lakes.
- Changing flow patterns.

Whether calculated by volume or number of impacted stream miles, soil in the water is the largest single pollutant in Tennessee. Some erosion is natural, however, tons of excess soil are lost every year as a result of human activities.

Preventive planning in land development projects can protect steams from siltation and protect valuable topsoil. Best Management Practices (BMPs) such as the installation of silt fences and maintenance of trees and undergrowth as buffer zones along creek banks can prevent soil entering the creek. Farming practices that minimize land disturbance such as fencing livestock out of creeks and no-till practices contribute greatly to protecting our waters.

2. Habitat Alteration

Many streams in Tennessee appear to have impaired biological communities, in the absence of obvious chemical pollutants. Often the cause is physical alteration of the streams which results in a loss of habitat. Habitat is often removed by agricultural activities, urban development, bridge or other construction, and /or dredging.

The Division uses an EPA method to score the stream habitat by evaluating ten components of habitat stability. This is a standardized way to identify and quantify impacts to stream habitat. Tennessee has developed regional guidance based on reference data to evaluate habitat (Arnwine and Denton, 2001). This is discussed in more detail in Chapter XII.

A permit is required to modify a stream in Tennessee. The permit will not be issued unless the water resources can be protected.

3. Pathogens

Pathogens are disease-causing organisms such as bacteria or viruses that can pose an immediate and serious health threat if ingested. Many bacteria and viruses that can be transferred through water are capable of causing serious or even fatal diseases in humans. The main sources for pathogens are untreated or inadequately treated human or animal fecal matter.

Water quality criteria use indicators to test for the presence of pathogens. Tennessee traditionally used total fecal coliform counts as the indicator of risk, but is in the process of finalizing a shift to an *E. coli* -based criteria. The *E. coli* group is considered by EPA to be a better indicator of true human risk.

Water contact like swimming, wading, splashing or fishing in water contaminated with these pathogens could have dangerous consequences. Currently, Tennessee has 32 streams and rivers posted for no water contact due to high pathogen levels. See Chapter IX for more specific information on these streams and rivers.

4. Nutrients

Another problem in Tennessee waterways is elevated nutrient concentrations. The main sources for nutrient enrichment are agricultural activities, wastewater plants, urban runoff, and improper application of fertilizers. Nutrients stimulate algae growth that produces oxygen during daylight hours, but uses oxygen at night, leading to significant diurnal fluctuations. Elevated nutrient levels cause the aquatic life in a stream to shift towards groups tolerant to organic loadings and leads to a reduction in biological diversity.

Types of Nutrients Impacting Tennessee Streams (Where Specified)

Nutrient	Stream Miles Impacted
Nitrate-Nitrite…….	694.9
Phosphorus…….	235.0

Note: Streams can be impacted by more than one nutrient, so these totals are not additive.

Streams with elevated nutrients often have floating algal mats and clinging filamentous algae. Nutrient pollution is difficult to control. Restrictions on point source dischargers alone may not solve this problem. The other major contributors to nutrient problems are agricultural activities like over application of fertilizers and intensive livestock grazing.

Some states have banned the use of laundry detergents containing phosphates. Therefore, most commercially available detergents do not contain phosphates. Many fertilizers for crops or lawn application contain both nitrogen and phosphorus. If fertilizers are applied in heavy concentrations, rain will carry the fertilizer into nearby waterways.

The ecoregion study has increased understanding of the natural distribution of nutrients throughout the state. Using this information Tennessee is in the process of developing regional water quality criterion for nutrients (Denton et al., 2001). More information on the proposed nutrient criteria can be found in Chapter XII.

5. Low Dissolved Oxygen

Low levels of dissolved oxygen in water will restrict or eliminate aquatic life. The water quality standard for dissolved oxygen in non-trout streams is currently five parts per million. While some species of fish and aquatic insects can tolerate lower levels of oxygen for short periods of time, prolonged exposure may affect biological diversity and in extreme cases, cause massive fish kills.

Low dissolved oxygen levels are usually caused by the decay of a large amount of organic material. This condition can be improved by reducing the amount of organic matter entering a stream. Streams that receive substantial amounts of ground water inflow can have naturally low dissolved oxygen levels.

Tennessee is in the process of studying dissolved oxygen patterns at reference streams. The results of these investigations may lead to adjustments of the current dissolved oxygen criterion. It is thought that a regional criterion that reflects natural fluctuations would be more appropriate than the current one-size-fits-all approach. Chapter XII discusses this project in more details.

6. Metals

Types of Metals Impacting Tennessee Streams (Where Specified)

Metal	Stream Miles Impacted
Iron	131.8
Manganese	94.9
Lead	88.2
Copper	56.3
Mercury	27.1
Zinc	11.9
Aluminum	7.2

Note: Streams can be impacted by more than one metal, thus these totals are not additive.

Metals can pose a serious health threat. The most common metals that impact Tennessee waters include copper, lead, iron, and manganese. Occasionally, zinc, mercury, and aluminum levels can also violate water quality standards. The major concern regarding metal contamination is toxicity to fish and aquatic life, plus the danger it poses to people who come in contact with the water or eat fish from the contaminated waterbody.

In particular, mercury can be a serious threat to human health due to bioconcentration in the food chain. East Fork Poplar Creek and North Fork Holston River are currently posted against fish consumption due to mercury. This is discussed in more detail in Chapter IX.

Occasionally, metals are elevated in streams due to natural conditions. For example, elevated manganese levels in west Tennessee streams may be naturally occurring in the groundwater. However, it is relatively rare for streams to violate standards simply on the basis of natural conditions.

7. Organic Contaminants

Organic contaminants are man-made chemicals containing the element carbon. These include chemicals like PCBs, pesticides and dioxins. These substances include, but are not limited to, compounds listed by EPA as priority pollutants. EPA classifies organic pollutants such as PCBs, chlordane, DDT and dioxin as probable human carcinogens (cancer causing agents).

In some streams these substances have accumulated in sediment and pose a health threat to those that consume fish or shellfish. Currently, seven rivers and streams are posted for dangerous levels of organic pollution. Five of the listed streams and rivers, McKellar Lake (Mississippi River), Loosahatchie River, Mississippi River, Nonconnah Creek, and Wolf River are located in west Tennessee. The other two streams are located in east Tennessee: Chattanooga Creek and East Fork Poplar Creek.

Some organic pollutants in very low concentrations can pose a threat to human health. Unfortunately, organic substances remain in the environment for a very long time. Many of these compounds have been banned from use for several decades. However, organic pollution that occurred decades ago still poses a serious threat. This is discussed in more detail in Chapter IX.

One problem in identifying organic pollution is that the water quality criteria are often below current detection levels. Tennessee currently has no numeric organic sediment criteria. Detection of these substances is generally made either by fish tissue levels and/or by use of sediment screening values provided by EPA.

8. pH

Low pH or elevated alkalinity, or even a significant change in the pH or acidity of the water over a relatively short period of time, will greatly impact aquatic life. A common reason for a change in pH is runoff from active or abandoned mine sites that lowers the pH of a creek and make it more acidic. Excessive amounts of algae can cause streams to violate standards on the alkaline side, but this phenomenon more commonly occurs in lakes.

pH also plays an important role in the toxicity of metals, with levels below 5.5 generally increasing toxic effects. The current criterion for the support of fish and aquatic life is a pH of 6.5 to 9.0. The Division is developing a proposal to revise the pH criterion to reflect natural conditions in the various ecoregions. Currently, 376 stream miles are listed as impaired by low pH. Most of these impacted streams are in areas with significant amounts of historical mining activities.

9. Flow Alteration

Two hundred and fifty-five stream miles are currently assessed as impaired by flow alteration. One source of flow alteration is channelization, the straightening and widening of channels. Channelization destroys habitat and increases sediment transport to downstream waters. Increased stream velocities following channelization causes extreme down-cutting of stream channels.

One of the most common sources of flow alterations is dams. In extreme cases, the receiving stream downstream of the dam does not have enough water flow to support aquatic life. Additionally, water released from the bottom of reservoirs can have very poor quality. Streams impacted by flow alterations due to dams and the management of reservoirs include: the Obey River (Dale Hollow), Caney Fork River (Center Hill), Stones River (Percy Priest), South Fork Holston River (Fort Patrick Henry and South Holston), Holston River (Cherokee), French Broad (Douglas), Tennessee (Fort Loudoun), Obed River (Lake Holiday), Hiwassee River (Apalachia), Ocoee River (Ocoee 1, 2, & 3), Elk River (Woods and Tims Ford), and the Duck River (Normandy).

Walter Hill Dam on the East Fork Stones River. Old mill dams such as this are common in Middle Tennessee. They usually do not cause a flow alteration problem due to the amounts of water seepage under and around the structure.
(Photo by Annie Goodhue, Nashville EAC.)

B. Causes Of Pollution In Reservoirs and Lakes

Some of the same types of pollutants that occur in rivers and streams impact reservoirs, although to different magnitudes. The main pollutants in reservoirs are organic substances such as PCBs, chlordane, and dioxins, as well as siltation, nutrients, and low DO (Figure 12 and Table 7). The effects of most of these pollutants are the same as in flowing water. However, substances are more likely to accumulate and remain in reservoirs for a very long time.

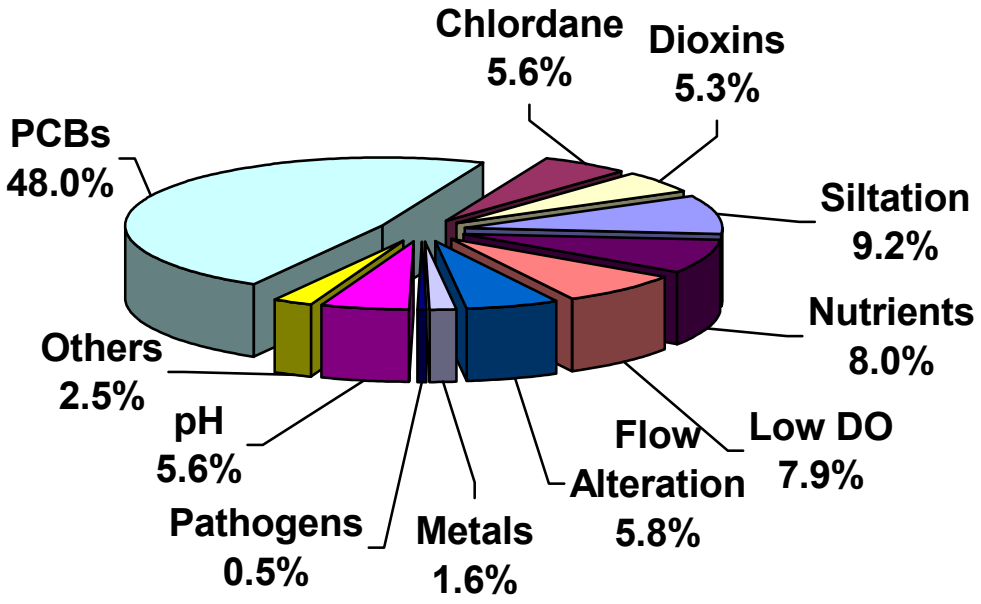

Figure 12: Relative Impacts of Pollution in Assessed Reservoirs. (Includes Reelfoot Lake)

1. Organic Substances

Priority organic substances such as PCBs, dioxins, and chlordane are the cause of pollution in almost sixty percent of the impaired lake acres. Since reservoirs serve as sediment traps, once a pollutant gets into the sediment it is very difficult to remove. Once in the sediment, these materials move through the food chain and can become concentrated in fish tissue. People eating fish from the waterbody will also bioconcentrate these substances.

PCBs were extensively used in the US for industrial and commercial uses until they were banned in 1978. Unfortunately, over 1.5 billion pounds of PCBs were produced before the ban. It is not known how many tons ended up in waterways. Unsafe levels of PCBs have been found in fish tissue collected from seven reservoirs. These include Fort Loudoun, Boone, Tellico, Watts Bar, Nickajack, and Melton Hill reservoirs in east Tennessee and Woods Reservoir in middle Tennessee.

Dioxin is a man-made by-product of herbicide manufacturing, certain historical papermill manufacturing processes, plus the incineration of chlorine-based chemicals. Dioxins are considered among of the most toxic substances released into the environment as EPA has found no "safe exposure level". EPA has determined that dioxins are not only "probable carcinogens", but also cause reproductive and developmental problems. Dioxin has been detected in several reservoirs.

Chapter IX has specific information on posted reservoirs and the health hazards of eating contaminated fish. Currently, 115,928 lake acres are posted for organic contamination.

2. Siltation

As in rivers and streams, siltation causes significant problems in reservoirs. Three reservoirs, Ocoee # 3, Ocoee #2, and Davy Crockett, have almost filled in with sediment due to siltation caused by upstream disturbances. Since reservoirs and lakes serve as sediment traps, once sediment enters a lake it tends to settle out, initially in embayment and headwater areas, but ultimately throughout the lake. It is difficult and expensive to remove sediment from reservoirs.

3. Nutrients

Another major impact in reservoirs and lakes is nutrients. Reelfoot Lake comprises 98 percent of the reservoir and lake acres currently listed as impacted by nutrients in Tennessee. When reservoirs and lakes have elevated levels of nutrients, the amount of algae and other aquatic plants dramatically increase. Green plants produce oxygen during daylight hours and use oxygen at night. As aquatic vegetation dies and decays, oxygen is depleted and may drop below the levels needed for fish and other aquatic life.

As reservoirs and lakes age, they go through a process called eutrophication. When this occurs naturally, it is caused by a gradual accumulation of the effects of nutrients over hundreds of years. Ultimately, eutrophication results in the filling in of the lake from soil, silt, and organic matter from the watershed. Pollution from human activities can greatly accelerate this process.

Tennessee's water quality criterion for nutrients in lakes is currently narrative. Our assessment basis is to consider lakes impaired if the level of eutrophication present interferes with the intended uses of the lake. This process is complicated by the complex nature of the public's uses for lakes and reservoirs. For example, algae production can help some species of fish thrive, which can be seen to benefit sport fishermen. However, swimmers and boaters prefer clear water.

Stages of Eutrophication:

1. **Oligotrophic** lakes are young lakes with relatively low levels of nutrients and high levels of dissolved oxygen. Since these lakes have low nutrient levels, they also have little algae and aquatic vegetation.

2. **Mesotrophic** lakes have moderate amounts of nutrients, but maintain a high level of dissolved oxygen. This results in more algae and aquatic vegetation that serve as a good food source for other aquatic life yielding a high biological diversity.

3. **Eutrophic** lakes have high levels of nutrients and therefore, high amounts of algae. Often, in the summer, an algae bloom will occur causing the dissolved oxygen levels to drop in the lake's lower layer.

4. **Hypereutrophic** lakes have extremely high nutrient levels. The algae at this stage are so thick it sometimes makes the lake look like pea soup. The dissolved oxygen in the lower layer of the lake may drop to the point where fish and other aquatic life cannot survive. Lakes that are hypereutrophic do not typically support the uses for which they are designated.

4. Dissolved Oxygen

The dissolved oxygen (DO) minimum water quality standard for reservoirs and lakes is five mg/L measured at a depth of five feet unless the lake is less than ten feet deep. If the lake is less than ten feet deep the DO is measured at mid-depth. In eutrophic reservoirs the DO can be much lower than five mg/L. Even in reservoirs that have a DO of five mg/L at the prescribed depth, the dissolved oxygen levels can be near zero deeper in the reservoir.

The most common reason lakes and reservoirs have fish kills due to low DO is eutrophication. Overproduction of algae raises oxygen levels while the sun is out, but on cloudy days and at night, the resulting algae die-off can cause DO levels to plummet. Additionally, high levels of biomass will restrict light penetration to a few feet or even inches. Below the depth where light can penetrate, DO levels will be very low.

DO levels in lakes and reservoirs can also be affected by discharges from upstream dams. Usually water from near the bottom of the reservoir is discharged from dams resulting in very low DO levels in the receiving stream. Currently, 15,637 lake and reservoir acres are listed as impacted by organic enrichment and/or low DO.

Table 7: Causes Of Impairment In Assessed Rivers And Reservoirs*

Cause Category	Impaired Rivers and Stream Miles	Impaired Reservoir/Lake Acres
Conventional Pollutants		
Siltation	4860.5	18,186
Suspended Solids	13.9	
Nutrients	1591.2	15,738 **
Organic Enrichment\ Low DO	1199.9	15,637 **
Pathogens	3423.7	1004
Toxic Pollutants		
Metals	431.5	3,254
Pesticides	1.1	
Chlordane	78.3	11,090
PCBs	128.9	94,468
Dioxins	86.7	10,370
Other Priority Organics	23.8	
Nonpriority Organics	72.3	
Undetermined Toxicity	136.0	
Inorganic Pollutants		
Unionized Ammonia	52.0	
Chlorine	12.2	
Sulfates	69.0	
Salinity\TDS\Chlorides	22.4	
pH	376.0	10,955 **
Other Inorganics	6.7	
Hydrologic Modifications		
Flow Alterations	256.2	11,444 **
Thermal Modifications	102.8	
Other Habitat Alterations	4370.3	
Noxious Aquatic Plants		4,555 **
Other Causes		
Oil and Grease	51.9	
Taste and Odor	6.7	45
Algal Growth	2.4	
Unknown Cause	58.0	

*Note - Rivers and reservoirs can be impaired by more than one cause. Rivers include both river and stream miles. Data in this table should only be used to indicate relative contributions. Totals are not additive.

** The majority of impaired lake acres in these categories are in Reelfoot Lake